The Long Path of Photons out of the Sun

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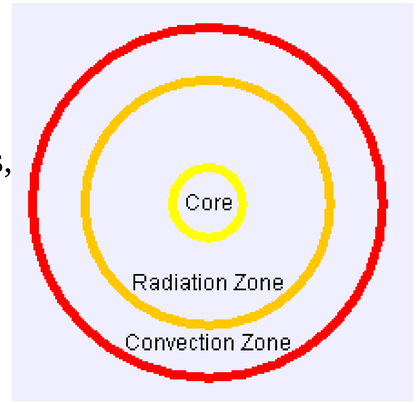
Introduction



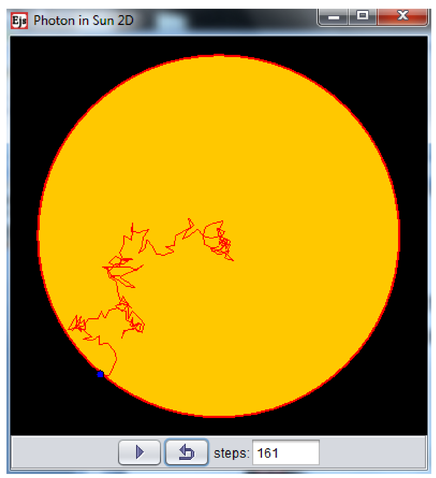
Photons leaving the Sun do not travel a straight path out of the Sun. Instead, they collide with other particles, transferring their energy as they go along. These photons, created in the core of the Sun, emanate in the form of gamma radiation [6], essentially bouncing off other particles in all different directions. Before reaching the vacuum of space and travelling to Earth, these constantly redirected γ-rays gradually make their way through the three major areas of the Sun's center—the core, the radiation zone, and the convection zone. Each section has different characteristics affecting the path of the photon.

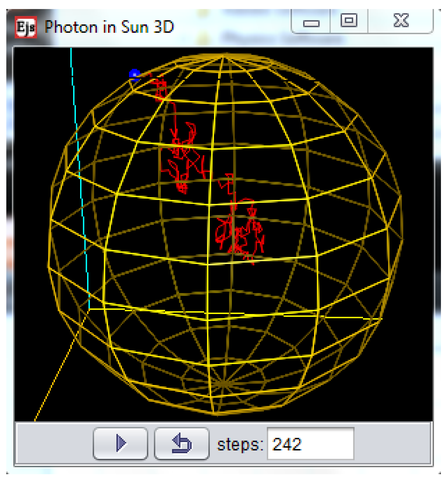
Simulation

In this project, we assumed that the path of photons due to these continuous collisions could be modeled with a random walk in polar coordinates. The step size of the walk was determined by the mean free path *l* of photons, dependent on the average density and opacity of the Sun as given by Equation 1: [5]

$$l = {}^{1}/_{\kappa\rho} \qquad 1$$

Then experiments were done using values of the density and the opacity that vary as the photon moves further away from the center of the Sun. Screenshots of the random walk simulation appear below, in both two dimensions and in three dimensions.





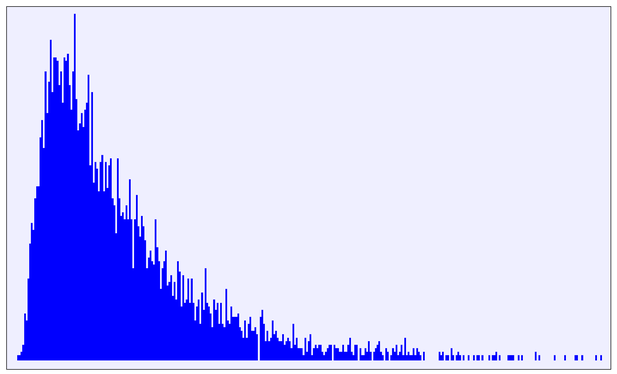
The simulation determines the average escape time and ensures that the path is indeed random.

Results

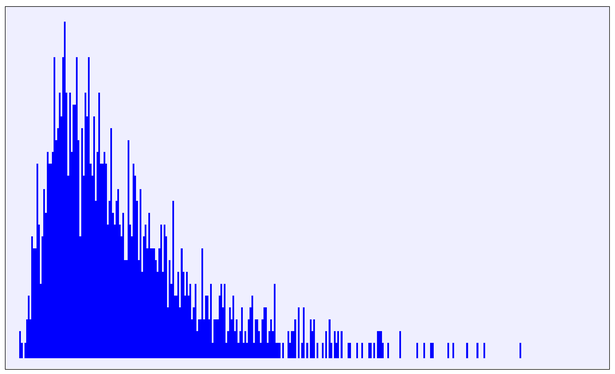
We found that the time it took the photons in our simulation to escape from the sun roughly followed a chi-squared distribution for the two-dimensional model. Since the escape positions were distributed normally along each individual axis, it makes sense that along two axes the distribution would be the square of the normal: χ^2. Additionally, the three-dimensional model followed a very similar kind of gamma distribution.

Histograms of Time Distribution

For Two Dimensions



For Three Dimensions



Conclusion

We used a random walk to evaluate the time it takes photons to escape from the Sun, based on the density and opacity of various regions of the sun. Our simulation generated the distribution of times, allowing us to calculate the average escape time.

References

[1] Christian, Wolfgang. EJS adaption of ``An Introduction to Computer Simulation Methods: Applications to Physical Systems," by Harvey Gould, Jan Tobochnik, and Wolfgang Christian

[2] Easy Java Simulations: http://www.um.es/fem/EjsWiki/

[3] Harwit, Martin. *Astrophysical Concepts: Third Edition*. New York: Springer-Verlag, 2000.

[4] Mitalas, R. & Sills, K. R. "On the photon diffusion time scale for the Sun" *The Astrophysical Journal*, v.401: 759-760. 1992.

[5] OSP Collection on the ComPADRE Digital Library: http://www.compadre.org/osp/

[6] Walker, Lisa May. "The random walk of radiation from the Sun." 2006.